Reply to Melott's
Comment on "Discreteness Effects in Lambda Cold Dark Matter Simulations: A Wavelet-Statistical View" by Romeo et al.

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ABSTRACT

Melott has made pioneering studies of the effects of particle discreteness in N-body simulations, a fundamental point that needs careful thought and analysis since all such simulations suffer from numerical noise arising from the use of finite-mass particles. Melott (arXiv:0804.0589) claims that the conclusions of our paper (arXiv:0804.0294) are essentially equivalent to those of his earlier work. Melott is wrong: he has jumped onto one of our conclusions and interpreted that in his own way. Here we point out the whys and the wherefores.

1. MELOTT'S CLAIM VS. THE FACTS

1.1. Our Approach

The first point raised by Melott concerns our approach. He states that we perform simulations with truncated power spectra to investigate the effect of initial small-scale power, and that this approach was introduced by him and collaborators.

The scope of our paper is much wider than that, and we cite Splinter et al. (1998) among others (cf. Sect. 1). We even quote Melott (2007), a non-refereed astro-ph note submitted

as a comment/review. And we do that in the central part of the Introduction, where we motivate our paper and point out what is new: (1) we assess the actual significance of discreteness effects against statistical scatter; (2) we offer a deeper and wider view of such effects through a thorough wavelet-statistical analysis; (3) we probe particular aspects of the problem, such as the range of scales affected by discreteness and a variety of statistical effects arising from the initial conditions. Thus, when commenting on our approach, Melott compresses the scope of our paper into a subitem of point (3) and our 80 simulations into one of the eight subsets!

1.2. Our Conclusions

Melott then comments on our conclusions, which he compresses into a single sentence: "They conclude that discreteness effects are visible in the simulations on all scales $\epsilon < 2d$ where ϵ is the force resolution (sometimes called 'softening'), and d is the mean interparticle separation". He states that our conclusions are essentially the same as those previously discussed by him and collaborators.

Our first conclusion is that dynamical evolution does not propagate discreteness noise up from the small scales at which it is introduced (cf. Abstract). This is one important aspect of the robustness of cosmological N-body simulations, which we can prove rigorously thanks to new and powerful wavelet statistics. The point is that the final power spectra, correlation functions and mass variances only show marginal differences, if any, once their scatter is taken into account (see Sects 3.1 and 3.2). This is also true for diagnostics that are sensitive to the phase of the density fluctuations (see Sects 3.3 and 4.2). One needs minimum-scatter phase-sensitive statistics, such as our wavelet set, to show that discreteness noise is not propagated upwards (see Sects 4.2, 4.3 and 6.1).

Our second conclusion is that one should aim to satisfy the condition $\epsilon \sim 2d$, where ϵ is the force resolution and d is the interparticle distance (cf. Abstract). This condition involves several aspects of discreteness, which appear if there is unbalance between force and mass resolution: initial non-Gaussianity from Gaussian initial conditions, departure from lognormality and rise of further complexity at low redshifts (cf. Sect. 7). This is a fresh view of the problem, which we discuss together with its implications. Concerning the range of scales affected by discreteness, $\epsilon \lesssim s \lesssim 2d$, this is a result that again we can prove rigorously thanks to our wavelet statistics. Previous attempts to quantify this point (e.g., Splinter et al. 1998) neglected the statistical scatter of the diagnostics, which generally dominates over the systematic effects of discreteness, as pointed out above (cf. first conclusion).

1.3. Our Implications

Let us finally remark that the implications of our work are *NOT* those expressed by Melott, when commenting on cosmological codes. *We* conclude that discreteness effects can be kept under control by implementing our condition $\epsilon \sim 2d$ adaptively, not only in AMR codes but also in tree-based codes, and clarify how (cf. Sect. 7).